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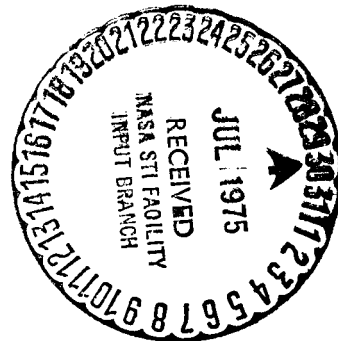
Semi-Annual Report for
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John R. Dickel

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Principal Investigator



I. PERSONNEL

Dickel has continued to work part time at no charge as the principal investigator. Dr. John C. Webber has also participated some, at no charge, in the observations of Saturn described below. Mr. Richard Karman and Mr. David Ther have each held $\frac{1}{2}$ -time research assistantships during the summer months. We anticipate that we shall be able to retain Mr. Ther as a research assistant during the coming academic year.

II. BUDGET

Because of the lack of a research assistant during the past academic year these funds remain available for next year, and so we anticipate being able to extend the present funding until May 21, 1976. An extension request has been mailed to the Grants Office. Other budget categories are approximately on schedule.

III. RESEARCH PROGRAM

A. Jovian ammonia band

The observations of the Jovian ammonia band in December 1974 and described in the previous report have now been analyzed and compared with the Pioneer models of Jupiter's upper atmosphere. The early analysis was compared with Kliore's preliminary presentation (at the DPS meeting of the AAS in February 1975) and gave very confusing results, but after learning of his revisions and seeing Orton's model at the IAU Colloquium

on Jupiter in Tucson in May 1975, I made new comparisons which are more reasonable. A preliminary version of a paper on that analysis is appended.

B. Eros

A second appendix is a paper which was presented to the Eros Workshop in Tucson on May 23-24, 1975. This represented a valuable cooperative effort with T. Pauliny-Toth and A. Witzel at the Max Planck Institut für Radioastronomie in Bonn. Basically they did the observing, the reduction was handled together, and Dickel finished up the analysis.

C. Saturn

The question of a magnetosphere around Saturn, the second largest giant planet, has been speculated upon ever since Jupiter's magnetosphere was discovered. Early microwave measurements have not revealed an excess of emission which would be expected from the synchrotron radiation, but in any event the signals at the longer wavelengths, where this emission would be expected, are very weak and better observations have been necessary. In addition, Brown (Ap. J. Letters, 198, L89, 1975) has suggested weak decameter burst radiation apparently from a small magnetosphere. To check these possibilities further Dickel and Webber undertook a series of observations of Saturn at a wavelength of 18-cm in March-April 1975 using the 120-foot telescope here at Illinois. Because the planet was faint enough so that

it could not be detected on a single scan, many passes have to be added together and also the sky background at the position of the planet has to be mapped after the planet has moved away in order to remove the effects of confusion noise in the background. The background observations were made in June. Mr. Karman is currently performing the editing, averaging, subtraction of records, etc. to determine the results.

D. Satellites and Other Asteroids

As radio telescopes and receivers continue to improve, it is becoming possible to obtain reliable measurements on more of the lesser bodies of the solar system. Good radio measurements, when compared with optical and infrared data, will help to establish the dielectric and thermal properties of the near subsurface layers of these objects. To this end we have proposed, together with E. K. Conklin of NAIC and B. L. Ulrich of NRAO, to measure the brightness temperatures of Titan, Ganymede, Callisto, Ceres, Vesta and hopefully a few other minor planets and satellites at a wavelength of 3 mm using the NRAO 36-foot telescope. We hope this will be scheduled in the fall of 1975. In anticipation, Mr. Ther has been continuing the development of an analysis program to evaluate 2-layer dielectric surfaces with various thermal and electric properties, using the microwave brightness temperatures in conjunction with radii and albedos from IR and optical work. When completed it should be valuable for interpreting many future data.

THE MICROWAVE SPECTRUM OF AMMONIA IN JUPITER'S ATMOSPHERE

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Abstract: High frequency-resolution observations of the microwave inversion lines of ammonia in Jupiter have been compared with the models of the temperature inversion in the stratosphere of the planet to deduce that much of the ammonia must be frozen out in the cloud layer leaving a smaller mixing ratio above.

Recent empirical models of Jupiter's upper atmosphere from Pioneer 10 and 11 data (Orton 1975; Kliore 1975) suggest that the planet has a temperature inversion in its upper atmosphere above the stratosphere. Although the detailed structure of the inversion region is not yet available, I have examined the crude models to see the effect of this high temperature layer upon the microwave spectrum of the ammonia inversion transitions near a wavelength of 1.26 cm. Two significant conclusions emerge from this quick look: (1) in order to get the low brightness temperature observed in the center of the ammonia band (about 130 kelvins which is also approximately the effective temperature of the planet) the total ammonia opacity in the temperature-inversion region must be small and (2) for any reasonable pressure the individual lines in the ammonia spectrum will be smeared sufficiently by pressure broadening to show little fine structure in the spectrum. These conclusions have been confirmed with observations by ourselves and others.

1. Mean Brightness Temperature

Broadband observations of the microwave emission in the vicinity of the ammonia band have been made by a number of workers over several years (see the review by Dickel, Degioanni, and Goodman 1970; Wrixon, Welch and Thornton 1971; Gulkis, Klein and Poynter 1974). The major problem in obtaining an accurate brightness temperature remains that of absolute calibration. As part of a high resolution spectroscopy program discussed below some mean brightness temperature measurements were made centered on

the 1,1 inversion transition at a frequency of 23.694 GHz in December 1974 using the 36-meter telescope at the Haystack Observatory. This telescope is very effective for such measurements because, although atmospheric extinction is still important, the telescope gain is not dependent upon ambient conditions and can be well calibrated as a function of position. The telescope was equipped with a maser amplifier with a noise temperature of 200 kelvin and a nominal bandwidth of 20 MHz. Beam switching was employed for both scans and on-off measurements of the planet on four successive days. The resultant brightness temperature was 139 ± 5 K (internal error only). The absolute calibration was made by comparison with observations of the compact H II region DR21. As discussed by Dent (1972) this source has a very well understood spectrum so that its flux density at 23.694 GHz of 19.04 janskys should be accurate to 3%. Thus the final absolute brightness temperature of Jupiter at 23.694 GHz is 139 ± 7 K which is in good agreement with the previous measurements.

This value indicates that the Jovian atmosphere must become opaque in the ammonia band at a level with approximately this temperature and that the hotter region above must have little effect. The ammonia cannot merely be in its vapor pressure equilibrium throughout the whole region because the high temperature of the upper region would release too much ammonia into the vapor phase creating too great an opacity. A likely hypothesis is that the ammonia is almost entirely frozen out of the atmosphere in the cold stratosphere and above this region it maintains

the low vapor-phase mixing ratio found in the cold region below. Using the original models calculated by Goodman (1969) with an ammonia mixing ratio of 0.0002 and an effective temperature for the planet of 130 K, but with the added temperature inversion layer from Orton (1975), I find that the reduced ammonia abundance must be less than 1/100 of the mixing ratio found in the warm convective region of the atmosphere below the clouds. The details of the temperature profile with height are not as important in determining the observed brightness temperature as is the change in ammonia mixing ratio.

2. Fine Structure in the Spectrum

The ammonia remaining in the high levels will still create some opacity but being at very low pressure should create only narrow features upon the smoother continuum of pressure broadened absorption lines from the cooler regions below. Because of the low mixing ratio required above, however, the lines are not very strong. The temperatures of the individual lines near the band center should differ by less than about 2 K from the gaps between the lines where their wings overlap.

This small value for the fine structure has been roughly confirmed by our high resolution observations of the spectrum between the 1,1 line at 23,694 GHz and the 2,2 line at 23.723 GHz. These data were obtained with the 100 channel autocorrelation receiver and the maser amplifier at Haystack described above so that some tuning was required to cover the full spectral interval. This somewhat limited both the continuity and the integration time available but the upper limit to any fine structure in the spectrum was less than 3% of the continuum level. Thus,

the individual lines were less than 4 K in brightness temperature above the surrounding continuum in confirmation of the models.

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UPPER LIMIT TO THE 2 CM BRIGHTNESS TEMPERATURE OF ASTEROID 433 EROS

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Abstract: The brightness temperature of 433 Eros was less than 360 kelvin during the close opposition in January 1975.

The minor planet 433 Eros was observed at a wavelength of 2 cm between 21 and 29 January 1975 using the 100-meter radio telescope of the Max Planck Institut für Radioastronomie, which has an aperture efficiency of about 0.35 at that wavelength. The observations were made by scanning across the planet in a dual beam-switching mode and the total integration time during which the asteroid was within one of the 1-arcmin beams was 450 minutes. The rms noise on the records was 0.55 millijanskys and the object was marginally detected in the noise with a flux density of 0.75 (\pm 0.65 standard error of the fit to the data) millijanskys. We therefore consider our result a non-detection and adopt a 2-rms upper limit of < 1.1 millijanskys for the flux density of Eros during that period.

Using the distance from the earth during those dates of 0.152 AU, we find a brightness temperature for Eros of $T_B < 10.4 \times 10^4 / D^2$ kelvin where D is the apparent mean diameter in km. Because the observations were spread over 6-8 hours per night, no correction was made for rotation and it is appropriate to adopt a mean diameter for the asteroid. From Dunlap's (1976) analysis for a rotating ellipsoid, we adopt projected diameters at minimum of 12×12.8 km and at maximum of 12×36 km. The mean value of D^2 is thus 293 km^2 and $T_B < 360 \text{ K}$. Because Eros was at phase angles of less than 9° during our observations, it is reasonable to compare the observed limit with the expected temperature of a uniform disk at the distance of Eros from the sun. With an albedo of 0.20 for

Eros (Zellner 1976; Morrison 1976), this expected temperature is 350 K. Thus our limit is insufficient to allow a detailed evaluation of the radio emissivity of Eros but it does indicate that the surface is not unusually hot and that the thermal properties of the material do not deviate markedly from the expected values.

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this volume

(values used, ^{will} taken from data given
at the Eros workshop on 23-24 May 1975)